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Dietary Value of *Artemia* Enriched with Various Types of Oil for Larval Striped Knifejaw and Red Sea Bream

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Two experiments were conducted to compare the dietary value of *Artemia* enriched with various types of oil, such as triglycerides (TG), methyl esters (ME), ethyl esters (EE), and free fatty acids (FFA) containing about 43% of n-3 highly unsaturated fatty acids (n-3HUFA), based on the growth, survival and chemical compositions of larval striped knifejaw and red sea bream.

Both larval striped knifejaw and red sea bream fed on nauplii enriched with TG, ME, and EE for 10 and 14 days showed good results in growth, survival and activity tests. These nauplii contained 4.1–7.1% n-3HUFA on a dry basis. The former larvae fed on nauplii without treatment or fed on FFA (1.0–1.7% n-3HUFA) showed poor feed performances. Incorporation of n-3HUFA into *Artemia* by emulsified FFA was very low due to coagulation of FFA during enrichment, leading to poor feed performances. Red sea bream fed on newly-hatched nauplii with 1% n-3HUFA but without docosahexaenoic acid (DHA) showed a high survival rate, but quite low activity. The concentration of eicosapentaenoic acid (EPA) plus DHA in polar lipids of both species fed on nauplii without enrichment or with FFA was somewhat lower than that of fish fed on nauplii enriched with TG, ME, and EE. The value was highest in fish fed on EE-fed *Artemia*.

Thus, the dietary value of *Artemia* to both species was effectively improved by enrichment with TG, ME, and EE, especially with EE.

In the large scale seedling production of marine fish, brine shrimp *Artemia* have been widely employed as food, while formulated microbound diets are still in limited use.[1] To improve the nutritional quality of *Artemia* from the viewpoint of essential fatty acids (EFA), oils containing a high amount of n-3 highly unsaturated fatty acids (n-3HUFA) have been added to the culture medium of *Artemia*.

Recently, Izquierdo *et al.**3 have suggested that the methyl ester (ME) type of oil has some ill effects not only on rotifers but also on fish larvae fed on them. In a previous paper,[2] it was shown that ester-type oils were converted to triglycerides (TG) and incorporated into the TG fraction of *Artemia*, and a maximum incorporation of n-3HUFA was observed in *Artemia* fed with the ethyl ester (EE) type of oil for 24 h. On the other hand, it was also demonstrated that the free fatty acid (FFA) type of oil was comparatively ineffective for *Artemia* due to coagulation of emulsion during enrichment. These results suggest that nauplii enriched with emulsified TG, ME, and EE for 12–24 h are good food for marine larval fish.

This experiment was conducted to compare the dietary value of *Artemia* enriched with various types of oil, such as TG, ME, EE, and FFA containing about 43% of n-3HUFA, based on the growth, survival and chemical compositions of larval striped knifejaw *Oplegnathus fasciatus* (Experiment I) and red sea bream *Pagrus major* (Experiment II).

Materials and Methods

Feeding of Artemia with Various Types of Oil by the Direct Method

Newly-hatched nauplii of *Artemia* from Utah, USA were stocked into 100 *l* tanks at a density of 20–70 individuals/m*l* and enriched with 100 m*l* of an emulsion prepared from 5 m*l* oil, one raw

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*3 M. S. Izquierdo, T. Takeuchi, T. Arakawa, C. Kitajima, and T. Watanabe: Oral presentation at the annual meeting of Japan. Soc. Sci. Fish., in Tokyo, April 1988, p. 250.

egg yolk, 94 m*l* seawater, and 30 g baker's yeast for 22–24 h in Expt. I, and for 19–24 h in Expt. II. The details of the direct method for enrichment and fatty acid compositions of the experimental oils have been described in the previous paper.[2] The FFA-type oil was not used to enrich *Artemia* in Expt. II.

Feeding of Fish Larvae with Artemia

Feeding experiments were conducted twice (Expts. I and II) with larval striped knifejaw and red sea bream at the Aquaculture Research Laboratory of Nagasaki Prefectural Institute of Fisheries.

1. Striped knifejaw (Expt. I). Larval fish of 10.1±0.8 mm in total length, which had been reared with S-type rotifers fed on *Nannochloropsis* and omega-yeast,[3] were randomly divided into 10 groups (duplicate experiments) containing 200 fish each in 100 *l* polycarbonate tanks. They were fed respectively with one of five varieties of *Artemia* for ten days at a water temperature of 26.1–27.3°C. Seawater and aeration were supplied at 800 m*l*/min and 500 m*l*/min, respectively.

The feeding rate ranged between $(2–6)\times10^5$ nauplii/tank per day. At the end of the trial 50 fish were subjected to an activity test by holding them out of the water in a scoop net for 10 s, transferring them into a 30 *l* tank, and keeping them there for 24 h to check the fish's response to the stress. The survival rate was calculated by counting the initial and final numbers of fish and the number of daily moratalities. At the beginning and end of the experiment, the total length of 30 individual fish was measured and the results were statistically subjected to a significance test (*t*-test).

The final remaining fish were sampled and analyzed for mositure, lipid classes, and fatty acid compositions. The data in the tables and diagrams indicate the mean value of the duplicate experiments.

2. Red sea bream (Expt. II). Larval fish of 10.3±0.6 mm in total length, which had been reared with S-type rotifers fed on *Nannochloropsis* and omega-yeast[3] and with minced fish, were randomly divided into eight groups (duplicate experiments) containing 200 fish each in 100 *l* polycarbonate tanks. They were fed respectively with one of four varieties of *Artemia* for 14 days at a water temperature of 24.3–26.7°C. Seawater and aeration were supplied at 600 m*l*/min and 400 m*l*/min, respectively. The feeding rate ranged between $(2–10)\times10^5$ nauplii/tank per day. At the end of the trial 50 fish were subjected to an activity test by holding them out of the water in a scoop net for 30 s, transferring them into a 30 *l* tank, keeping them there for 24 h to check the fish's response to the stress. Calculations of survival rate, fish sampling, and analytical items were all as described in Expt. I.

Results and Discussion

Lipid Composition of Artemia in Expts. I and II

Moisture, lipid contents, lipid classes, and fatty acid compositions of *Artemia* enriched with various types of oil for 19–24 h are shown in Table 1. During the experimental period the

Table 1. Moisture, lipid content, lipid classes,*1 and n-3HUFA*2 contents in *Artemia* nauplii enriched with various types of oil for 19–24 h in Expts. I and II

	Experiment I					Experiment II				
	No	TG	ME	EE	FFA	Initial	No	TG	ME	EE
Moisture (%)	91.0	90.4	90.1	89.6	89.5	82.0	88.8	86.9	86.7	86.3
				(Dry weight, %)						
Total lipid	28.5	33.3	33.4	35.5	20.9	26.3	21.8	35.3	35.7	36.7
Polar lipid	20.2	16.8	15.9	15.8	12.1	15.5	16.9	18.1	20.6	20.4
TG	1.5	10.2	10.6	12.1	1.4	5.3	1.3	13.8	11.3	13.0
FFA	5.2	3.8	4.2	4.8	5.7	3.4	2.3	1.6	1.9	1.6
FS						0.3	0.7	0.5	0.5	0.4
DG (FS+DG+MG)	1.6	2.5	2.7	2.8	1.6	1.0	0.3	0.9	1.0	0.9
MG						0.7	0.2	0.3	0.2	0.3
n-3HUFA	1.3	4.1	5.3	5.4	1.7	0.9	1.0	6.5	6.4	7.1
EPA*2	1.1	3.2	4.1	4.2	1.5	0.7	0.8	4.7	4.9	5.4
DHA*2	ND	0.4	0.7	0.6	0.1	ND	ND	1.2	0.9	1.1

*1 TG, triglycerides; FFA, free fatty acids; FS, free sterols; DG, diglycerides; MG, monoglycerides.

*2 n-3HUFA, n-3 highly unsaturated fatty acids; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

nauplii fed on various types of oil except for the emulsified FFA were found to incorporate lipids effectively by the direct method. The contents of lipid, TG, and n-3HUFA in *Artemia* fed on emulsified TG, ME, and EE were high compared to those without treatment or those fed on emulsified FFA. In particular, the highest n-3HUFA content was observed in *Artemia* fed on emulsified EE. On the other hand, the FFA content was high in *Artemia* without enrichment or those fed on emulsified FFA. These results were almost the same as in the previous experiment.[2)]

Feeding of Larval Fish with Artemia in Expts. I and II

The results of 10 days' feeding of Japanese striped knifejaw and 14 days' feeding of red sea bream are shown in Table 2. Similar feeding results were obtained in both Expts. I and II. Larval striped knifejaw fed on nauplii enriched with TG, ME, and EE, which were high in the amount of n-3HUFA, ranging from 4.1 to 5.4%,[*1] showed good results in growth, survival, and activity tests. On the other hand, in the fish fed on nauplii without emulsified oil (the intact nauplii), containing a low amount of n-3HUFA, growth, survival rates and survival after the activity test were low. The fish fed on FFA-enriched *Artemia* containing 1.7%[*1] n-3HUFA also showed poor feed performances. A significant difference was observed in the total length of fish between those fed on nauplii enriched with TG, ME, and EE, and those fed on nauplii without treatment or with FFA. In red sea bream, growth and survival rates and survival after the activity test were all high in fish fed on nauplii emulsified with TG, ME, and EE. These nauplii contained 6.4 to 7.1%[*1] n-3HUFA. On the other hand, the fish fed on nauplii without emulsified oil, which contained 1.0%[*1] n-3HUFA but no docosahexaenoic acid (DHA), showed a high survival rate, but quite low activity. These results are in agreement with the recent report that larval red sea bream require at least 0.5–1%[*1] of DHA in *Artemia* to obtain a high activity value.[4),*2] It has also been demonstrated that DHA is found to be superior to eicosapentaenoic acid (EPA) as EFA for many marine larval and ju-

Table 2. Growth, survival rates, and survival rate after activity test in larval striped knifejaw after 10-day feeding and in larval red sea bream after 14-day feeding (%)

Tank no.	Final total length (mm)	Survival rate	Activity[*1]
Striped knifejaw (Expt. I)[*2]			
1 (No)[*3]	17.6±1.9[a*4]	62.3	7
2 (TG)	18.6±1.8[b]	99.8	99
3 (ME)	18.4±2.4[b]	98.3	100
4 (EE)	18.5±2.5[b]	99.0	100
5 (FFA)	17.4±1.8[a]	84.9	15
Red sea bream (Expt. II)[*5]			
6 (No)	21.6±1.6[a]	94.4	3
7 (TG)	23.9±1.7[b]	98.5	100
8 (ME)	23.9±1.7[b]	97.8	100
9 (EE)	23.7±1.4[b]	97.0	100

*1 Survival rate after activity test.
*2 Initial total length: 10.1±0.8 (Mean±S.D. n=30).
*3 See Table 1.
*4 Means with different superscripts are significantly different ($P<0.05$, Expt. I; $P<0.01$, Expt. II.).
*5 Initial total length: 10.3±0.6 (Mean±S.D. n=30).

Table 3. Moisture, lipid content, and lipid classes* of larval striped knifejaw and red sea bream fed on *Artemia* nauplii enriched with various types of oil in Expts. I and II

	Striped knifejaw (Expt. I)						Red sea bream (Expt. II)				
	Initial	No	TG	ME	EE	FFA	Initial	No	TG	ME	EE
Moisture (%)	84.0	81.4	81.6	81.6	81.5	81.2	82.5	81.6	79.8	79.7	79.5
	(Dry weight, %)										
Total lipid	13.2	12.8	14.4	16.7	18.2	11.4	15.4	11.0	18.9	19.6	21.0
Polar lipid	7.5	6.3	6.5	6.7	7.1	5.9	7.2	5.7	5.8	6.0	6.0
TG	0.3	0.6	1.3	2.5	3.3	0.3	0.4	0.6	7.5	8.9	10.2
FFA	2.0	2.6	3.3	4.2	4.4	2.6	3.6	1.6	2.7	2.2	2.3
FS	2.9	2.5	2.6	2.5	2.6	1.8	3.0	2.5	1.9	1.6	1.8
DG	0.2	0.3	0.3	0.4	0.4	0.1	0.4	0.2	0.5	0.4	0.4
MG	0.1	0.2	0.1	0.2	0.1	0.1	0.5	0.1	0.3	0.2	0.2

* See the footnote to Table 1.

*1 Dry matter basis.
*2 T. Takeuchi, M. Toyota, and T. Watanabe: Oral presentation at the annual meeting of Japan. Soc. Sci. Fish., in Tokyo, April 1991, p. 38.

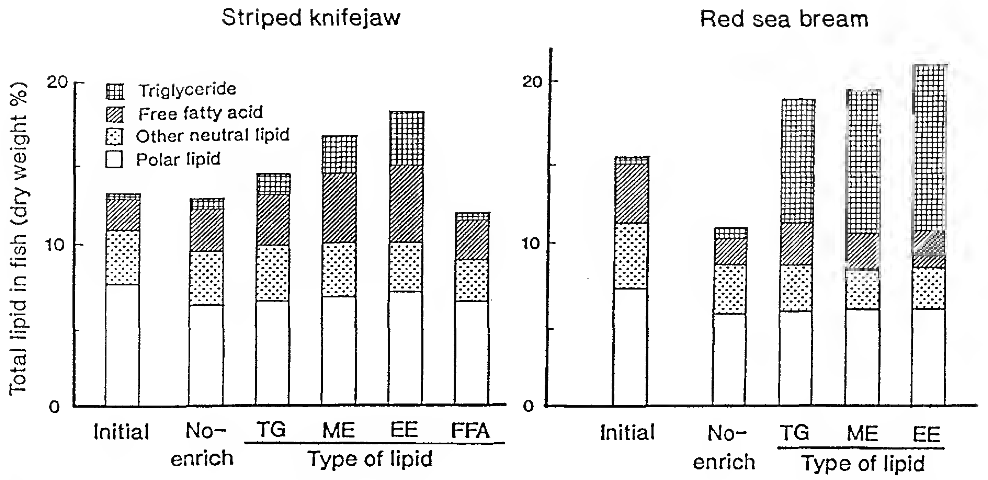

Fig. 1. Lipid classes of larval striped knifejaw and red sea bream fed on *Artemia* nauplii enriched with various types of oil.

Table 4. Fatty acid composition of neutral and polar lipids in larval striped knifejaw fed on *Artemia* nauplii enriched with various types of oil in Expt. I (area %)

Fatty acid	Neutral lipid						Polar lipid					
		Tank no.						Tank no.				
	Initial	1 (No)	2 (TG)	3 (ME)	4 (EE)	5 (FFA)	Initial	1 (No)	2 (TG)	3 (ME)	4 (EE)	5 (FFA)
14: 0	2.4	1.0	1.5	1.4	1.5	1.1	1.0	0.5	0.5	0.5	0.5	0.5
15: 0	0.6	0.2	0.2	0.2	0.2	0.2	0.7	0.2	0.3	0.3	0.2	0.2
16: 0	16.2	12.4	12.0	12.0	12.0	12.1	23.6	17.4	21.7	22.1	21.0	21.4
16: 1n-7	11.4	4.2	5.1	5.7	5.8	4.0	5.1	3.0	2.8	2.8	2.8	2.9
17: 0	1.1	0.8	0.7	0.7	0.7	0.7	1.5	0.8	1.0	0.9	0.9	1.1
16: 3n-6	0.8	1.0	0.9	1.0	0.9	0.9	0.7	0.8	1.0	1.0	0.9	0.7
18: 0	6.7	8.4	7.0	6.4	6.6	7.6	11.2	9.9	9.9	9.8	9.8	11.7
18: 1n-(9+7)	14.7	31.7	27.6	27.5	28.9	26.6	17.5	26.0	22.6	21.6	22.0	25.5
18: 2n-6	5.5	6.0	4.7	4.7	4.6	6.1	3.7	7.8	4.4	3.7	3.8	6.0
18: 3n-6	0.3	0.4	0.3	0.3	0.3	0.3	0.1	0.3	0.2	0.2	0.1	0.2
18: 3n-3	2.3	16.4	12.5	12.7	12.0	14.0	1.1	11.9	5.4	4.5	4.5	7.2
18: 4n-3	0.4	1.5	1.2	1.4	1.3	1.1	tr	0.6	0.3	0.2	0.3	0.3
20: 0	tr	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
20: 1	0.7	1.4	1.3	1.4	1.2	0.9	0.8	1.0	0.8	0.7	0.8	0.8
20: 2n-6	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.3	0.2	0.2	0.3
20: 3n-6	0.3	0.2	0.1	0.1	0.1	0.2	0.3	0.2	0.1	0.1	0.1	0.2
20: 4n-6	6.6	2.6	2.7	2.3	2.2	3.7	3.8	2.7	2.4	2.4	2.4	2.2
20: 3n-3	tr	0.6	0.4	0.3	0.4	0.5	0.1	0.6	0.3	0.3	0.3	0.6
20: 4n-3	0.9	0.8	0.6	0.6	0.7	0.7	0.4	0.8	0.4	0.4	0.4	0.5
20: 5n-3	16.5	5.5	11.0	11.2	11.0	11.6	9.2	7.8	11.0	11.2	11.9	6.7
22: 1	0.1	0.4	0.2	0.3	0.3	0.3	tr	0.2	0.1	0.1	0.1	0.2
22: 4n-6	0.6	0.5	0.4	0.3	0.2	0.5	0.4	0.4	0.3	0.3	0.2	0.5
22: 5n-6	tr	tr	tr	tr	tr	tr	tr	tr	0.1	0.1	0.1	0.1
22: 5n-3	4.3	0.5	2.1	2.0	2.0	1.7	6.2	1.4	3.2	3.1	3.2	2.0
22: 6n-3	3.9	0.4	4.2	4.0	4.1	2.3	6.0	1.0	7.9	8.8	9.2	2.2
Σ Saturates	27.3	23.0	21.6	20.9	21.2	21.8	38.3	29.0	33.6	33.7	32.6	35.3
Σ Monoenes	26.9	37.9	34.4	34.9	36.2	31.9	23.5	30.1	26.4	25.2	25.8	29.5
Σ n-6	14.1	10.9	9.3	8.8	8.5	12.0	9.2	12.7	8.8	7.9	7.8	10.4
Σ n-3	28.4	25.6	32.0	32.2	31.4	31.8	23.0	24.2	28.5	28.5	29.8	19.4
Σ n-3HUFA	25.7	7.8	18.3	18.2	18.1	16.7	21.9	11.6	22.9	23.8	25.0	12.0

venile fish.[5-7),*1,2]

Lipid Composition of Larval Fish

Moisture, lipid content, and lipid classes of larval striped knifejaw and red sea bream fed on *Artemia* nauplii enriched with various types of oil in Expts. I and II are shown in Table 3 and Fig. 1. The terminal fish given each *Artemia* in Expts. I and II showed low moisture in their bodies compared to those of the initial fish. The fish fed on nauplii without enrichment or enriched with emulsified FFA showed a low content of total lipid due to the decrease of TG, while it was increased in the fish fed on emulsified TG, ME,

Table 5. Fatty acid composition of neutral and polar lipids in larval red sea bream fed on *Artemia* nauplii enriched with various types of oil in Expt. II (area %)

Fatty acid	Neutral lipid					Polar lipid				
		Tank no.					Tank no.			
	Initial	6 (No)	7 (TG)	8 (ME)	9 (EE)	Initial	6 (No)	7 (TG)	8 (ME)	9 (EE)
14:0	0.8	1.1	1.5	1.2	1.4	0.5	0.4	0.5	0.5	0.5
14:1	0.8	0.6	0.5	0.4	0.5	0.3	0.2	0.1	0.1	0.1
15:0	0.4	0.3	0.3	0.2	0.2	0.4	0.2	0.2	0.2	0.2
16:0	9.9	13.5	11.4	11.3	11.6	18.5	19.2	20.8	21.7	21.6
16:1n-7	10.4	3.0	4.7	4.6	5.0	4.4	1.4	1.5	1.5	1.6
17:0	1.2	0.8	1.0	0.9	1.0	1.4	0.9	0.8	0.8	0.8
16:3n-6	1.5	1.1	0.9	0.8	0.8	0.9	0.7	0.5	0.5	0.4
16:3n-3	0.2	0.1	0.2	0.2	0.2	1.1	2.3	1.4	1.3	1.4
18:0	5.8	5.3	4.9	5.0	4.8	10.0	10.8	9.7	10.1	10.0
18:1n-9	13.4	18.7	20.1	20.3	19.7	11.3	17.8	13.8	13.8	13.5
18:1n-7	10.6	7.4	7.0	7.0	6.8	8.1	6.5	5.5	5.4	5.4
18:2n-9	tr	0.1	0.1	0.1	0.1	tr	0.2	0.2	0.1	0.1
18:2n-6	4.1	8.3	5.3	5.2	5.1	2.3	7.0	3.2	2.9	2.7
18:3n-6	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2
18:3n-3	3.2	18.3	14.6	14.3	14.1	1.1	9.1	3.9	3.6	3.4
18:4n-3	0.4	1.2	1.7	1.6	1.7	tr	0.4	0.2	0.2	0.2
20:0	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
20:1	0.8	0.9	1.5	1.5	1.6	0.5	1.2	1.2	1.1	1.2
20:2n-6	0.1	0.3	0.2	0.2	0.2	0.1	0.4	0.2	0.2	0.2
20:3n-6	0.1	0.3	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1
20:4n-6	4.0	3.1	1.3	1.4	1.4	3.2	2.9	2.4	2.2	2.1
20:3n-3	0.1	1.0	0.5	0.5	0.5	0.1	1.1	0.4	0.4	0.4
20:4n-3	1.0	1.0	0.8	0.9	0.9	0.5	0.9	0.4	0.4	0.4
20:5n-3	14.9	7.3	10.5	11.2	11.7	9.3	6.6	10.5	10.0	10.0
22:0	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1
22:1	0.3	0.1	0.3	0.3	0.2	0.1	0.1	0.1	tr	tr
22:4n-6	0.8	tr	tr	tr	tr	0.8	0.1	0.1	0.1	0.2
22:5n-6	0.2	tr	tr	tr	tr	0.3	tr	0.3	0.2	0.2
22:5n-3	1.7	0.5	1.8	1.9	1.9	2.8	1.6	3.5	3.5	3.7
22:6n-3	8.3	0.7	3.7	3.8	3.5	17.2	2.6	14.1	14.7	14.9
Σ Saturates	18.4	21.3	19.4	19.1	19.4	31.2	32.0	32.3	33.6	33.5
Σ Monoenes	36.4	32.3	35.1	35.2	34.9	24.9	27.9	23.0	22.7	22.4
Σ n-6	11.1	13.4	8.2	8.1	12.9	8.1	11.7	6.9	6.5	6.1
Σ n-3	29.8	30.2	33.8	34.4	34.4	32.1	24.6	34.5	34.2	34.3
Σ n-3HUFA	26.0	10.6	17.3	18.3	18.4	29.9	12.8	29.0	29.0	29.3

*1 A. Kanazawa, S. Kobayashi, S. Teshima, and S. Koshio: Oral presentation at the annual meeting of Japan. Soc. Sci. Fish., in Tokyo, April 1989, p. 48.

*2 M. Toyota, T. Takeuchi, T. Watanabe, F. Fujimoto, and K. Imaizumi: Oral presentation at the annual meeting of Japan. Soc. Sci. Fish., in Tokyo, April 1991, p. 38.

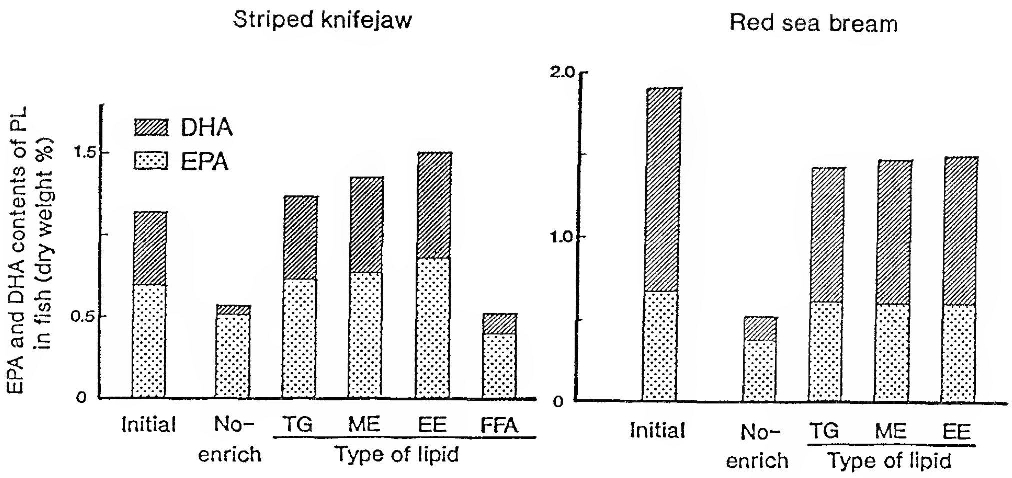

Fig. 2. EPA and DHA contents in the polar lipid from larval striped knifejaw and red sea bream fed on *Artemia* nauplii enriched with various types of oil.

and EE (Fig. 1). In particular, the highest contents of total lipid and TG were observed in fish fed on EE-enriched *Artemia*. Namely, the lipid content of larval fish was clearly reflected by that of *Artemia*. There was no marked difference in the polar lipid content and other neutral lipids between the treatments in Expts. I and II.

Fatty Acid Composition of Polar and Nonpolar Lipid Fractions in Larval Fish

The fatty acid compositions of polar and nonpolar lipid fractions from whole bodies of Japanese striped knifejaw and red sea bream are shown in Tables 4 and 5, respectively. The EPA and DHA contents of PL in fish are also illustrated in Fig. 2. The terminal fish given nauplii with various treatments in Expts. I and II showed high percentages of linolenic acid (18:3n-3) in polar and neutral lipid fractions of whole bodies compared to those of the initial fish. This result was due to the high amount of 18:3n-3 in the experimental nauplii, which is called the freshwater type.[8] EPA plus DHA contents of PL in fish fed on nauplii without treatment or those enriched with emulsified FFA in both experiments were quite low compared to those fed on nauplii with emulsified TG, ME, and EE (Fig. 2). Especially, the DHA content was markedly different between both the groups. This result agrees with the poor feed performances in fish fed on FFA-enriched nauplii containing an insufficient amount of n-3HUFA to satisfy the EFA requirement. In both the striped knifejaw and red sea bream, the maximum EPA plus DHA content was recorded for the fish fed on EE-enriched *Artemia*. The percentage of EPA was almost the same between polar and neutral lipid fractions in both Expts. I and II.

On the other hand, the percentage of DHA was much lower in nonpolar lipid fraction. It has been observed that the percentage of DHA in whole body neutral lipid markedly decreases compared with that of polar lipid, when larval and juvenile fish are fed on a diet containing low content of n-3HUFA or DHA.[4,5] Consequently, the amount of DHA in *Artemia* enriched with TG, ME, and EE in this experiment might not be sufficient for larval fish, even though larval fish showed good feed performances. Further experiments are needed to clarify the requirement of marine larval fish for DHA in *Artemia*.

From the former experiment, in which the n-3HUFA content of *Artemia* was high when EE-type oil was used for enrichment, and also from present observations, it may be concluded that the dietary value of nauplii for larval striped knifejaw and red sea bream is effectively improved by feeding the nauplii with the emulsion of an ester oil, particularly the ethyl ester type. On the other hand, it is also found that poor growth performance of fish fed on nauplii enriched with emulsified FFA was induced by poor incorporation of n-3HUFA into the nauplii due to coagulation of the FFA.

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